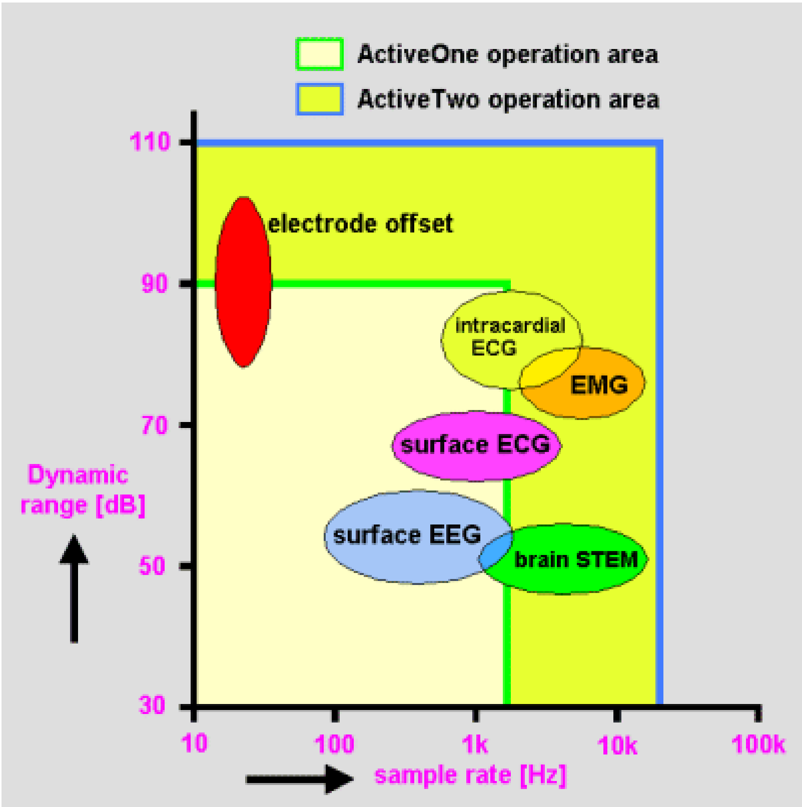
Advantages of a 24 bit System

The discussion about the the best choice of analog-digital converter for an biopotential measurement system is often confused by the habit of expressing the dynamic range in bits. The most important specification of an ADC is the dynamic range (the ration between maximal input signal and intrinsic noise level), which can be expressed in dB, or in effective bits (with each bit representing 6 dB dynamic range). ADCs are categorized by the number of bits of the generated digital output. However, the number of effective bits is always smaller than the length of the output.



Of the many types of ADCs available, two types have become most popular for applications in biopotential measurement applications: the Successive Approximation Register type ADC (SAR), and the Sigma-Delta ($\Delta\Sigma$) type converter. In general, the SAR type offers high speed and low power consumption, while the Sigma Delta type offers high dynamic range and good linearity, and no missing codes. All these features play a role in a biopotential measurement system, so the choice for the best type is often a complicated tradeoff. Modern SAR types often have a noise level close to the theoretical minimum of the quantization noise generated by the LSB value (RMS magnitude of the quantization noise is LSB/$\sqrt{12}$) . For example, the 16- bit converters used in our ActiveOne system had a dynamic range of nearly 90 dB (15 effective bits). With sigma delta types, each output word is calculated as an result of many coarse 1 bit conversions (hence the name: oversampling ADC), and the noise level is often much high than the quantization noise. For example, the 24-bit converters used in our new ActiveTwo system have a dynamic range of 115 dB (approx. 19 effective bits). So the 5 least significant bits can be regarded as noise.

To answer the question which ADC would be the best choice for an biopotential measurement system, it is instructive to reason in terms of optimal dynamic range of the converter. The plot at the left gives an impression of the signal amplitudes that can be expected. Using an ADC with a high dynamic range (many effective bits), and with a high sample rate, is attractive because it makes the system applicable for a broad range of biopotential measurements. However, increasing the number of bits and sample range quickly increases the power consumption, which we want to keep minimal to allow battery power supply.

Basically, there are two routes to go:

AC- Amp: Suppress the large offset potential with a reduced gain at low frequencies (by using one or more high pass stages in the amplifier). This leaves only the AC biopotential signal to be handled by the ADC. A 12 bit (EEG) to 14 bit (ECG) ADC is sufficient.

DC- Amp: Use an ADC with enough dynamic range to handle the offset potentials without any high-pass filtering

AC-coupled amplifier, is attractive because it uses the dynamic range of the ADC most effectively. Until approx. 10 years ago, this was the only option because ADCs that combined a dynamic range of more than approx. 80 dB and sufficient sample rate for biopotential measurements simply did not exist. The main disadvantages of the AC coupled setup are the delayed response after amplifier saturation (especially when high gain and long time constants are used), the loss of low frequencies from the signal (information about electrode drift is lost), and the differences in low frequency

response between the channels caused by tolerances of the coupling capacitors. These disadvantages made designers wishing for ADCs suitable to use a DC coupled amplifier with an ADC with sufficient dynamic range to capture the entire input signal (inclusive electrode offset voltages) without clipping.

In 1995, Analog Devices introduced a 22-bit converter optimized for biopotential measurement systems, the AD7716. This AD converter has a dynamic range of 100dB at 1kHz. Several competitors decided that the time of the DC coupled amplifier had arrived. The 22-bit systems currently marketed by BioSemi's competitors are based on this ADC, and they all suffer from the same limitations: limited sample rate, limited input range and high power consumption. So, untill 2001 BioSemi decided to keep using 16-bit alternatives, and used a combination of an AC coupled and a DC coupled amplier for the successful ActiveOne system. This system could be used in AC mode with large +/-330 mV electrode offset range, or in DC mode with a 66 mVpp input range.

The semiconductor industry has made major advances during the last years, and the recent introduction of fast low-power 24 bit Sigma-Delta ADC's with a dynamic range of more then 115 dB (more then 19 bit effective resolution) allows a new step forward in the design of biopotential measurement systems. BioSemi is proud to introduce the new ActiveTwo, the first system able to combine the best of both worlds. The ActiveTwo has all the advantages of the DC amplifier: measurement of all low-frequency information, no delay after saturation, and perfectly equal frequency response of all the channels (no high-pass, all low-pass filtering is digital). At the same time, the ActiveTwo is the first DC system which retains the advantages you have learned to appreciate in good AC designs of the past: tolerance for large electrode offset voltages (up to +/- 262 mV), options for

high sample rates (up to 16 kHz per channel) and minimal power consumption (<10 mW per channel).